AnoSpEx: A Spatially-Explicit Predictive Computational Model for Studying *Anopheles* Metapopulation Dynamics towards Malaria Control

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CERTIFICATION

It is hereby certified that this thesis, written by Oluwagbemi, Olugbenga Oluseun was supervised by Prof. E.F Adebiyi and Dr. J.L. Rasgon, and submitted to the Department of Computer and Information Sciences, School of Natural and Applied Sciences, College of Science and Technology, Covenant University, Ota, Nigeria.

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DECLARATION

It is hereby declared that this PhD research was undertaken by Oluwagbemi, Olugbenga Oluseun. His research was conducted in the **Johns Hopkins Bloomberg School of Public Health, Johns Hopkins University, Baltimore, Maryland, USA**, under the sponsorship of the United States Government through the Fulbright Fellowship Award and was also funded by grant from the NIH and the Bill and Melinda Gates Foundation to Dr. Jason Rasgon. The PhD thesis is based on his original study in the Department of Computer and Information Sciences, School of Natural and Applied Sciences, College of Science and Technology, Covenant University, Ota, Nigeria, under the supervision of Prof. Ezekiel Adebiyi and Dr. Jason L. Rasgon. Ideas and views of this research work are products of the original research undertaken by **Oluwagbemi, Olugbenga Oluseun** and the views of other researchers have been duly expressed and acknowledged.

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DEDICATION

I dedicate this PhD thesis to the living God who helped me to succeed; to my late grandfather, Pa. A.O.E Falako; and to my aunt, Mrs. Nike Aduloju.

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Olugbenga O. Oluwagbemi

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LIST OF ABBREVIATIONS

ABM – Agent-Based Model

AnoSpEx: *Anopheles* Spatially-Explicit

$CD_{t:}$ Cummulative Development of *Anopheles*

CDC: Center for Disease Control

CBT: Cattle Baited Trap

CIMSiM : Container inhabiting Mosquitoes Simulation Model

GUI: Graphical User Interface

HLC: Human Land Catch

ITNs: Insecticide Treated Nets

IRS: Indoor Residual Spraying

RH0: Development rate per hour at 25ºC assuming no temperature inactivation of the critical enzyme (hr^{-1})

DHA: Enthalpy of activation of the reaction catalyzed by the enzyme (cal/mol)

DHH: Enthalpy change associated with high temperature inactivation of the enzyme (cal/mol)

R: Universal gas constant

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ABSTRACT

Human malaria is one of the most important public health problems in many African countries, associated with high rates of mortality and morbidity. The disease presents a spectrum of complications ranging from mild and self-limiting illness to life threatening pathology. Malaria incidence has increased in Africa due to climate change, insecticide and drug resistance, and social/economic issues. As an infectious disease, malaria is most commonly transmitted through the bite of infected female *Anopheles* mosquitoes. Thus, one of the most effective methods to control the disease is by controlling the *Anopheles* mosquito vectors that transmit the parasites. Along this line, we developed a C++ based, stochastic spatially-explicit predictive computational model, which is biologically rich, weather data-driven, and parameterized by field data, to simulate *Anopheles* metapopulation dynamics towards understanding and validating the seasonal dynamics of this vector. This is aimed at providing a potential tool towards achieving the reduction and suppression of this vector. It is also to provide insight into effective, efficient and novel control strategies that can help achieve greater control of malaria. Understanding the seasonal dynamics of *Anopheles* mosquitoes would provide better platform for improving traditional and novel control interventions at suppressing and reducing the spread of malaria. Results produced by the model from several simulations were validated with real-life CDC light trap, CBT and HLC (Human Landing Catch) *Anopheles* mosquitoes field trap collection data from Macha, Zambia. The resulting model was shown to be a good, effective and potential tool for malaria control.